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Nakashiba

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(54) **SEMICONDUCTOR DEVICE, METHOD OF MANUFACTURING THE SAME, AND SIGNAL TRANSMITTING/RECEIVING METHOD USING THE SEMICONDUCTOR DEVICE**

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257/679; 438/48; 438/57; 336/200

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257/679, E21.022, 277; 438/48, 57; 336/30,
336/200; 323/206, 355, 232

See application file for complete search history.

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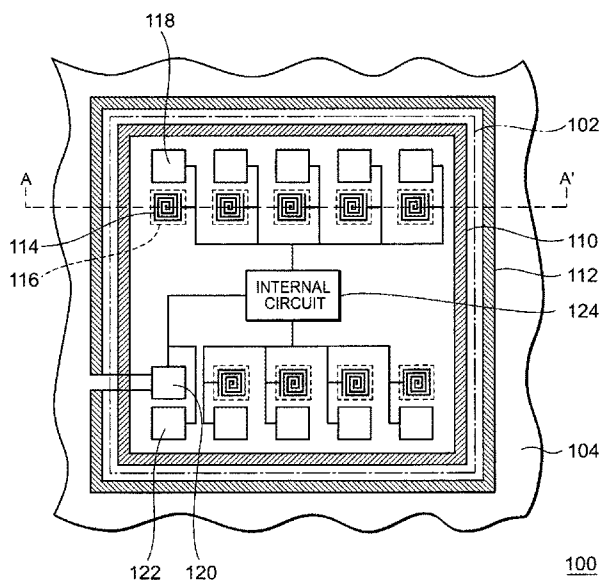
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(57) **ABSTRACT**

A semiconductor device includes an internal circuit provided on a substrate, a plurality of external terminals connected to the internal circuit, a plurality of wires connecting the internal circuit and the external terminals, and a plurality of inductors communicating with an external device. Each of the inductors is connected to each of the wires. The external terminals are formed in a region not to interrupt communication between the inductors and the external device.

12 Claims, 3 Drawing Sheets



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FIG. 1

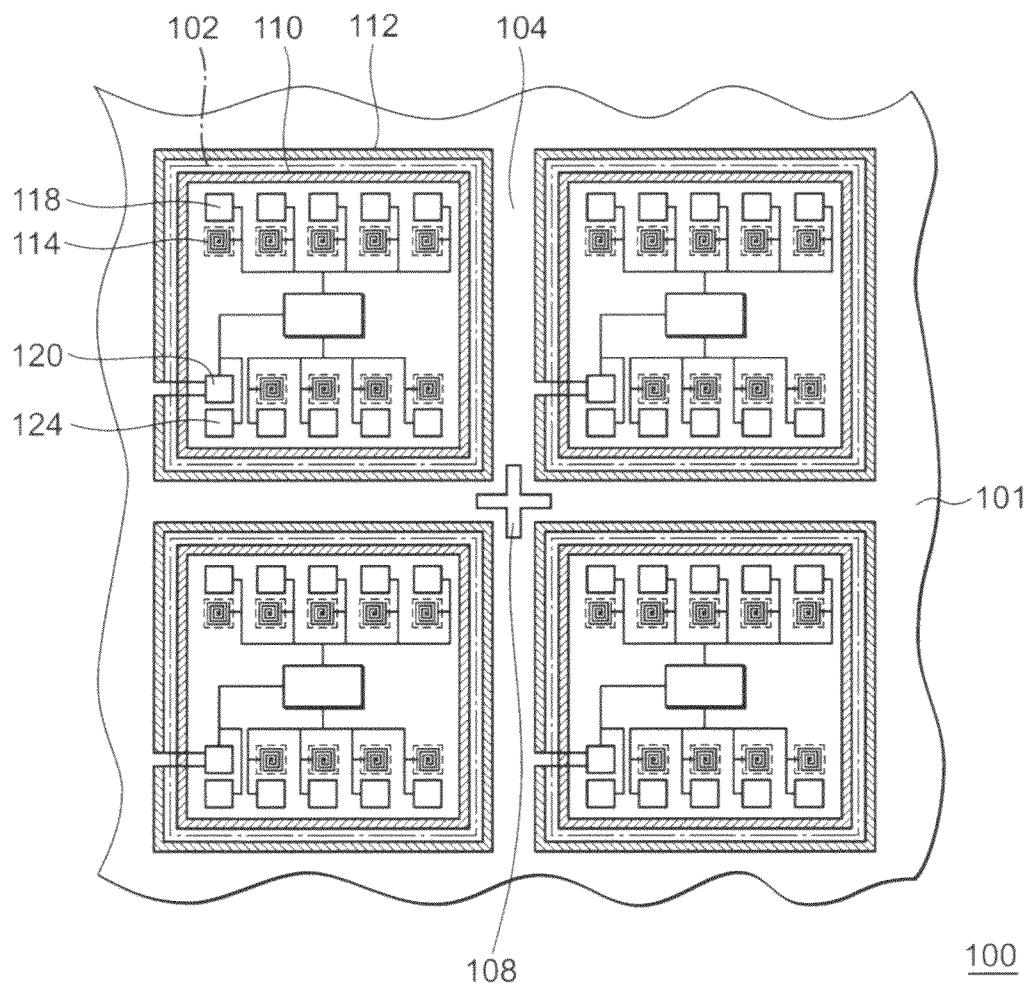


FIG. 2

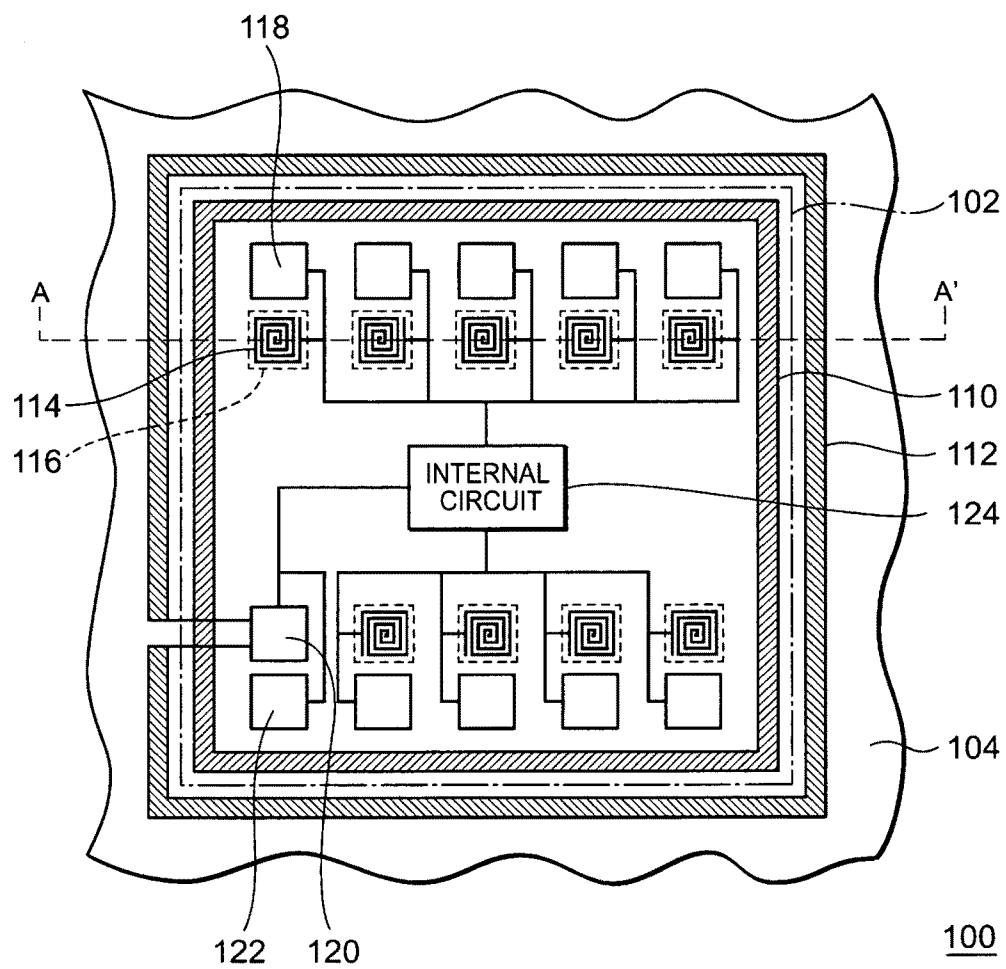


FIG. 3

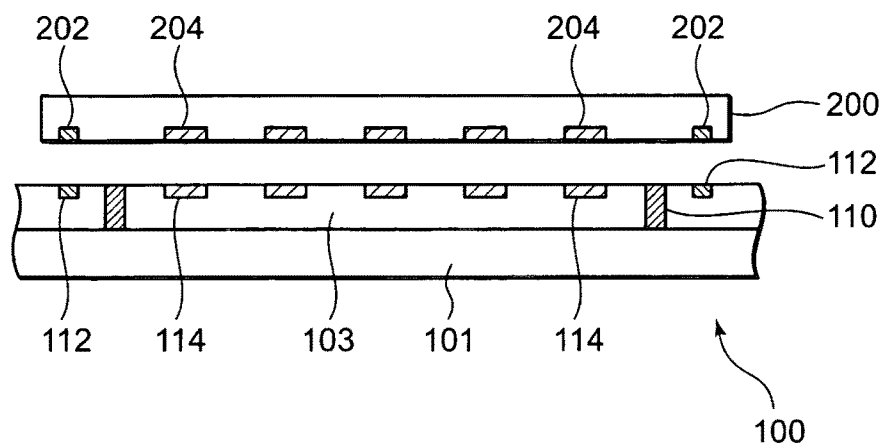
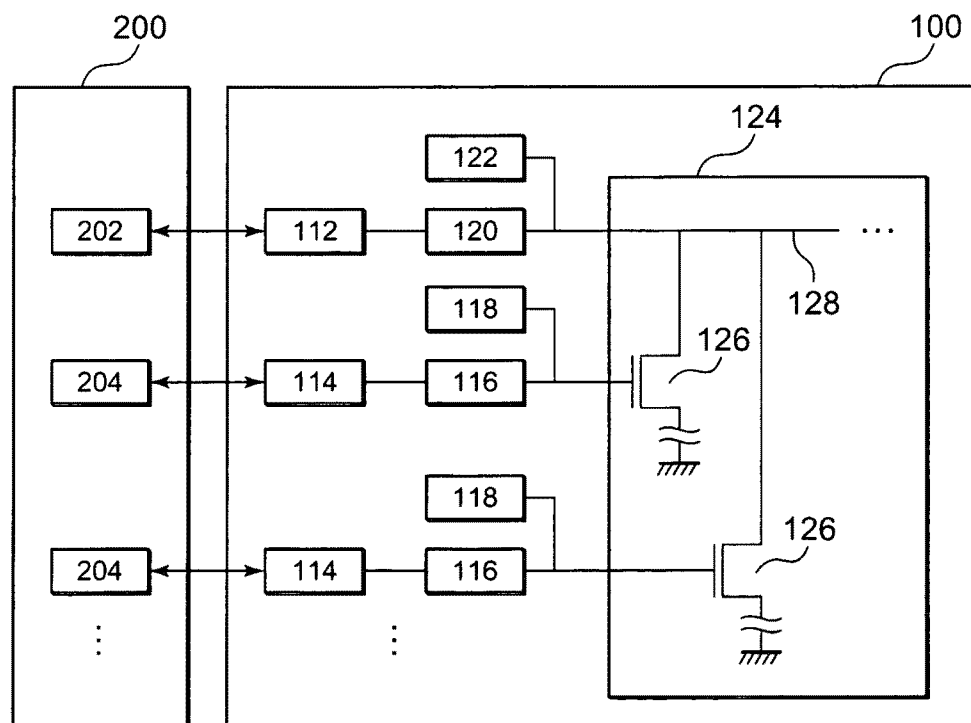


FIG. 4



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SEMICONDUCTOR DEVICE, METHOD OF MANUFACTURING THE SAME, AND SIGNAL TRANSMITTING/RECEIVING METHOD USING THE SEMICONDUCTOR DEVICE

The present application is a Continuation Application of U.S. patent application Ser. No. 12/292,820, filed on Nov. 26, 2008 now U.S. Pat. No. 8,004,054, which is based on and claims priority from Japanese patent application No. 2007-313821, filed on Dec. 4, 2007, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a semiconductor device, a method of manufacturing the same, and a signal transmitting/receiving method using the semiconductor device.

2. Description of Related Art

These days, a semiconductor device which communicates data by radio communication is known.

JP 2007-134694 A describes a semiconductor device which communicates data by electromagnetic induction. The semiconductor device includes a coiled antenna and a semiconductor integrated circuit connected to the coiled antenna. When the coiled antenna connected to a reader/writer is brought close to the semiconductor device, an AC magnetic field is generated from the coiled antenna connected to the reader/writer. The generated AC magnetic field passes through the coiled antenna contained in the semiconductor device, and an electromotive force is generated between terminals of the coiled antenna by electromagnetic induction, whereby the semiconductor integrated circuit contained in the semiconductor device is operated.

JP 2005-311331 A describes a structure in which an integrated circuit and an antenna are formed on the same substrate, and conductor wires or conductive films forming the antenna are formed in two layers so as to sandwich the substrate including the integrated circuit formed thereon. In JP 2005-311331 A, there is described an example in which the conductor wire formed in one layer serves as an antenna for supplying power to the integrated circuit, and the conductor wire formed in another layer serves as an antenna for transmitting/receiving a signal.

JP 2005-228785 A describes a structure in which a coiled antenna is disposed outside the profile of a circuit of a semiconductor chip. Further, JP 2005-30877 A describes a technology of mounting a built-in test circuit and a radio communication circuit in a semiconductor integrated circuit device, and controlling the built-in test circuit by a radio signal to run a test.

The present inventor has recognized as follows. Conventionally, in order to run a test on an internal circuit of a semiconductor device at a wafer level, for example, a pad of a chip surface of the semiconductor device is subjected to probing using a probe to supply the internal circuit with power, or a signal is transmitted/received for observation thereof. There arises a problem in that, for example, damage is caused to the pad by the probe during a probe test, which later leads to a poor connection in the case of bonding the pad, or in that the pad is scraped and small pieces are removed, which causes contamination. Moreover, along with a reduction in chip size and an increase in pads per one chip, a pad size and a pitch between the pads have been reduced, and hence it has become increasingly difficult to realize a sufficient electrical connection through application of a number of probes corresponding to a number of pads.

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In order to avoid the above-mentioned problem, it is desired that power be supplied to the internal circuit or the signal be transmitted/received to/from the internal circuit in a non-contact manner. However, in order to transmit/receive various signals to/from the internal circuit by, for example, electromagnetic induction instead of a plurality of pads to correspond to input/output signals to the plurality of pads, a large number of inductors are necessary, which increases an area required to provide those inductors. As described in JP 2007-134694 A, JP 2005-311331 A, and JP 2005-228785 A, with the structure in which the coiled antenna for transmitting/receiving a signal is arranged on a perimeter of the chip, a number of antennas cannot be arranged. Alternatively, in the technology described in JP 2005-30877 A, it is assumed that only one antenna coil is arranged for one chip, and power is generated using a carrier wave of a radio signal to be input from the outside. On the other hand, for supplying the internal circuit with power, large electromagnetic force is required.

SUMMARY

The present invention provides a semiconductor device, including:

- a semiconductor substrate including a semiconductor chip formation region;
- a chip internal circuit provided within the semiconductor chip formation region of the semiconductor substrate;
- a signal transmitting/receiving unit which is provided within the semiconductor chip formation region of the semiconductor substrate, transmits/receives a signal to/from an outside in a non-contact manner by one of electromagnetic induction and capacitive coupling, and transmits/receives a signal to/from the chip internal circuit through electrical connection to the chip internal circuit; and
- a power receiving inductor which has a diameter provided along an outer edge of the semiconductor chip formation region of the semiconductor substrate so as to surround the chip internal circuit and the signal transmitting/receiving unit, receives a power supply signal from the outside in the non-contact manner, and is electrically connected to the chip internal circuit.

The present invention also provides a signal transmitting/receiving method, including:

- bringing an external device close to a semiconductor device in a non-contact manner,

the semiconductor device including:

- a semiconductor substrate including a semiconductor chip formation region;
- a chip internal circuit provided within the semiconductor chip formation region of the semiconductor substrate;
- a signal transmitting/receiving unit which is provided within the semiconductor chip formation region of the semiconductor substrate, and transmits/receives a signal to/from the chip internal circuit through electrical connection to the chip internal circuit; and
- a power receiving inductor which has a diameter provided along an outer edge of the semiconductor chip formation region of the semiconductor substrate so as to surround the chip internal circuit and the signal transmitting/receiving unit, and is electrically connected to the chip internal circuit,

the external device including:

- a power supply inductor corresponding to the power receiving inductor; and
- an external signal transmitting/receiving unit which transmits/receives a signal to/from the signal trans-

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mitting/receiving unit in the non-contact manner by one of electromagnetic induction and capacitive coupling; and

transmitting/receiving the signal between the external signal transmitting/receiving unit and the signal transmitting/receiving unit, and transmitting/receiving a power supply signal between the power supply inductor and the power receiving inductor.

With the structure described above, the signal transmitting/receiving unit can be formed to be smaller than the power receiving inductor to be provided inside the power receiving inductor, with the result that an increase in chip size can be limited even when a plurality of the signal transmitting/receiving units are arranged. On the other hand, a diameter of the power receiving inductor can be increased, and hence a signal large enough to supply a power supply voltage can be obtained.

The present invention also provides a method of manufacturing a semiconductor device, including:

bringing an external device close to a semiconductor device in a non-contact manner,

the semiconductor device including:

a semiconductor substrate including a semiconductor chip formation region and a scribe line region provided around the semiconductor chip formation region;

a chip internal circuit provided within the semiconductor chip formation region of the semiconductor substrate;

a signal transmitting/receiving unit which is provided within the semiconductor chip formation region of the semiconductor substrate and transmits/receives a signal to/from the chip internal circuit through electrical connection to the chip internal circuit;

a power receiving inductor which has a diameter provided along an outer edge of the semiconductor chip formation region of the semiconductor substrate so as to surround the chip internal circuit and the signal transmitting/receiving unit, and is electrically connected to the chip internal circuit;

a bonding pad which is provided in the semiconductor chip formation region of the semiconductor substrate correspondingly to the signal transmitting/receiving unit and is electrically connected to the chip internal circuit; and

a power supply bonding pad provided in the semiconductor chip formation region of the semiconductor substrate while being electrically connected to the chip internal circuit,

the external device including:

a power supply inductor corresponding to the power receiving inductor; and

an external signal transmitting/receiving unit which transmits/receives a signal to/from the signal transmitting/receiving unit in the non-contact manner by one of electromagnetic induction and capacitive coupling;

transmitting/receiving the signal between the external signal transmitting/receiving unit and the signal transmitting/receiving unit;

transmitting/receiving a power supply signal between the power supply inductor and the power receiving inductor;

cutting the semiconductor device along the scribe line region into chips; and

connecting, in each of the chips of the semiconductor device, the bonding pad and the power supply bonding pad to

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the external signal transmitting/receiving unit and an external power supply circuit through a bonding wire, respectively.

With the structure described above, before the semiconductor substrate is cut into chips, the signal is transmitted/received in the non-contact manner, and at the same time, a power supply voltage can be supplied in the non-contact manner when a test is run at a wafer level.

It should be noted that a semiconductor device or a method in which the above-mentioned components are appropriately combined or a description of the present invention is changed therebetween is also effective as an aspect of the present invention.

According to the present invention, the power supply can be made sufficiently in the non-contact manner while limiting an increase in chip size when various signals are transmitted/received in the non-contact manner.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, advantages and features of the present invention will be more apparent from the following description of certain preferred embodiments taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a plan view illustrating a structure of a semiconductor device according to an embodiment of the present invention;

FIG. 2 is a plan view illustrating a structure of a semiconductor chip formation region and a structure of a scribe line region provided around semiconductor chip formation region in detail;

FIG. 3 is a cross-sectional view taken along a line A-A' of FIG. 2; and

FIG. 4 is a block diagram illustrating the structure of the semiconductor device and a structure of a tester.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereinafter, an embodiment of the present invention is described with reference to the drawings. It should be noted that similar components are denoted by similar reference numerals in the respective drawings, and their descriptions are appropriately omitted. In this embodiment, a description is given of a case where, as an example, when a test is run on a chip internal circuit provided within a semiconductor device at a wafer level, various test signals are transmitted/received to/from an external tester in a non-contact manner, and at the same time, the semiconductor device is supplied with a power supply voltage in the non-contact manner.

FIG. 1 is a plan view illustrating a structure of a semiconductor device 100 according to this embodiment.

The semiconductor device 100 includes a semiconductor substrate 101. A plurality of semiconductor chip formation regions 102 and a scribe line region 104 provided around the semiconductor chip formation regions 102 are formed on a surface of the semiconductor substrate 101. FIG. 1 illustrates four semiconductor chip formation regions 102, and an alignment mark 108 is provided there among in the scribe line region 104.

FIG. 2 is a plan view illustrating a structure of one semiconductor chip formation region 102 and a structure of the scribe line region 104 provided around the semiconductor chip formation region 102 in detail.

The semiconductor device 100 includes a chip internal circuit 124, a plurality of signal transmitting/receiving inductors 114 (signal transmitting/receiving units), a plurality of bonding pads 118, a plurality of conversion circuits 116, a

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power supply circuit **120**, and a bonding pad **122**, which are each provided within the semiconductor chip formation region **102**. The bonding pad **118** and the bonding pad **122** are pads to be later subjected to wire bonding.

In a conventional semiconductor device, the signal transmitting/receiving inductor **114** can be provided in place of a pad which is provided for probing the internal circuit using a probe at a wafer level. Conventionally, when probing is performed using the probe, pad is damaged, and when bonding is performed in the damaged portion, the bonding may cause a poor connection. Therefore, a probing region and a wire-bonding region need to be provided for the pad, and thus the size thereof is increased. In this embodiment, the bonding pad **118** needs to include only the wire-bonding region, whereby the size thereof can be reduced compared with the conventional pad.

It should be noted that the signal transmitting/receiving inductor **114** is provided in the vicinity of a surface of the semiconductor device **100** so as to transmit/receive a signal to/from the external device. In addition, the bonding pad **118** is provided in the vicinity of the surface of the semiconductor device **100** so as to be later subjected to wire bonding. On the other hand, the conversion circuit **116** does not need to be provided in the vicinity of the surface of the semiconductor device **100** because the conversion circuit **116** just converts the signal transmitted/received to/from the external device by the signal transmitting/receiving inductor **114**. Therefore, the conversion circuit **116** can be provided so as to overlap the signal transmitting/receiving inductor **114** in a laminating direction of the semiconductor substrate, with the result that an increase in size of the semiconductor device **100** can be limited.

The conversion circuits **116** are each provided under the signal transmitting/receiving inductors **114** correspondingly to the respective signal transmitting/receiving inductors **114**. The each signal transmitting/receiving inductor **114** is electrically connected to the chip internal circuit **124** through the corresponding conversion circuit **116**. The conversion circuit **116** modulates/demodulates the signal transmitted/received between the chip internal circuit **124** and the outside. Moreover, the each bonding pad **118** is electrically connected to the chip internal circuit **124**.

Further, the semiconductor device **100** includes a seal ring **110** provided on a perimeter portion of the each semiconductor chip formation region **102** and a power receiving inductor **112** provided around the seal ring **110**. The power receiving inductor **112** has a diameter provided along an outer edge of the each semiconductor chip formation region **102** so as to surround the plurality of signal transmitting/receiving inductors **114** and the plurality of bonding pads **118**. The power receiving inductor **112** has one end and another end, which are connected to the power supply circuit **120**. The power supply circuit **120** is, for example, a rectifier circuit. The power receiving inductor **112** is connected to the chip internal circuit **124** through the power supply circuit **120**. The signal transmitting/receiving inductor **114** and the power receiving inductor **112** can be formed in a coil shape.

The bonding pad **122** is electrically connected to the chip internal circuit **124**. The bonding pad **122** is connected to a power supply circuit outside the chip through a bonding wire after the semiconductor device **100** is cut along the scribe line region **104** into chips. Then, power is supplied to the chip internal circuit **124** through the bonding pad **122** from the power supply circuit outside the chip. It should be noted that the bonding pad **122** can also be formed in a smaller size

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compared with the conventional pad, because it is sufficient that the bonding pad **122** includes only the wire-bonding region.

FIG. **3** is a cross-sectional view taken along a line A-A' of FIG. **2**. Here, a structure of a tester **200** which supplies the semiconductor device **100** with a signal is also illustrated.

The semiconductor device **100** includes the signal transmitting/receiving inductors **114**, the seal ring **110**, and the power receiving inductor **112** within an insulating layer **103** provided on the semiconductor substrate **101**. The tester **200** includes a plurality of signal transmitting/receiving inductors **204** provided at positions corresponding to the signal transmitting/receiving inductors **114** provided within the semiconductor chip formation region **102** of the semiconductor device **100** and a power supply inductor **202** provided correspondingly to the power receiving inductor **112** of the semiconductor device **100**.

FIG. **4** is a block diagram illustrating the structure of the semiconductor device **100** and the structure of the tester **200**.

The chip internal circuit **124** can include a plurality of transistors **126** corresponding to the plurality of signal transmitting/receiving inductors **114**. One end of a source and a drain of the each transistor **126** is grounded, and another end thereof is connected to the power supply circuit **120** or the bonding pad **122** through a power supply line **128**. In this case, a back surface of the semiconductor substrate **101** can be grounded so that one end of the transistor **126** is connected to the back surface of the semiconductor substrate **101** to be grounded. Besides, gates of the transistors **126** are each connected to the signal transmitting/receiving inductors **114** through the conversion circuits **116**. Further, the gates of the transistors **126** are each also connected to the bonding pads **118**. It should be noted that an input/output buffer circuit may be inserted between the transistor **126** and the bonding pad **118** or between the transistor **126** and the conversion circuit **116**, which is not illustrated in FIG. **4**.

Next, an operation when the semiconductor device **100** according to this embodiment receives a signal from the tester **200** is described with reference to FIG. **2** to FIG. **4**.

First, the tester **200** is brought close to any chip of the semiconductor device **100** so that the signal transmitting/receiving inductor **204** and the power supply inductor **202** of the tester **200** are opposed to the signal transmitting/receiving inductor **114** and the power receiving inductor **112** of the semiconductor device **100**, respectively. Then, the signal transmitting/receiving inductor **204** and the power supply inductor **202** of the tester **200** output, to the semiconductor device **100**, radio waves each having a predetermined frequency. In this case, a test signal and a power supply signal are output from the signal transmitting/receiving inductor **204** and the power supply inductor **202**, respectively.

The power receiving inductor **112** of the semiconductor device **100** converts the signal output from the power supply inductor **202** into an AC electrical signal. The power supply circuit **120** generates a power supply voltage based on the AC electrical signal converted by the power receiving inductor **112** and supplies the generated power supply voltage to the chip internal circuit **124**. The signal transmitting/receiving inductor **114** of the semiconductor device **100** converts the signal output from the signal transmitting/receiving inductor **204** into an AC electrical signal. The conversion circuit **116** demodulates the AC electrical signal converted by the signal transmitting/receiving inductor **114** and supplies the demodulated AC electrical signal to the chip internal circuit **124**. When a signal is output from the semiconductor device **100** to the tester **200**, the conversion circuit **116** modulates the electrical signal supplied from the chip internal circuit **124**

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and supplies the modulated electrical signal to the signal transmitting/receiving inductor **114**. The signal transmitting/receiving inductor **114** outputs the modulated electrical signal as a radio wave to the corresponding signal transmitting/receiving inductor **204** of the tester **200**. Accordingly, data is transmitted/received and power is supplied between the semiconductor device **100** and the tester **200**.

In this embodiment, the diameter of the power receiving inductor **112** can be increased, whereby a signal large enough to supply the power supply voltage can be obtained. Moreover, the signal transmitting/receiving inductor **114** is formed to be smaller than the power receiving inductor **112** so that the signal transmitting/receiving inductor **114** is included within the power receiving inductor **112**, and thus an increase in size thereof can be limited even if a plurality of signal transmitting/receiving units are provided.

Further, in this embodiment, the power receiving inductor **112** is provided around the seal ring **110**, and hence the power receiving inductor **112** can be caused to function as a chipping stop layer when wafer dicing is performed along the scribe line region **104**. In addition, the power receiving inductor **112** can be used as a chipping sensor for detecting an occurrence of chipping in the semiconductor chip.

The embodiment of the present invention has been described with reference to the drawings, which is an example of the present invention, and various structures other than the above-mentioned structure can also be adopted.

In the embodiment described above, the case where the signal transmitting/receiving unit serves as an inductor has been described as an example. However, the signal transmitting/receiving unit may serve as a capacitor, and data may be transmitted/received to/from an external device such as the tester **200** by capacitive coupling.

Further, in the embodiment described above, the description has been made of the case where various test signals are transmitted/received in a non-contact manner to/from the external tester when a test is run on the chip internal circuit of the semiconductor device at the wafer level. However, the present invention can also be applied to a case where various signals are transmitted/received in the non-contact manner after the semiconductor substrate is cut into chips. Moreover, the power receiving inductor **112** may be provided within the seal ring **110**.

It is apparent that the present invention is not limited to the above embodiments, but may be modified and changed without departing from the scope and spirit of the invention.

What is claimed is:

1. A semiconductor device, comprising:
 - a first circuit provided over a substrate;
 - a first external terminal connected to the first circuit;
 - a first wire connecting the first circuit and the first external terminal;
 - a first inductor connected to the first wire;
 - a second circuit connected to the first circuit;
 - a second inductor connected to the second circuit;

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a second wire connecting the second circuit and the first circuit;

a second external terminal connected to the second wire, wherein, in a plan view, the second inductor surrounds the first external terminal, the second external terminal, the second circuit, the first circuit, and the first inductor.

2. The semiconductor device according to claim 1, wherein the first circuit comprises a plurality of transistors.

3. The semiconductor device according to claim 1, wherein, in a plan view, the first circuit, the second circuit, the first external terminal, the second external terminal, the first wire, the second wire, the second inductor, and the first inductor are surrounded by a seal ring.

4. The semiconductor device according to claim 1, wherein, in a plan view, the second circuit, the first circuit, the first external terminal, the second external terminal, the first wire, the second wire, and the first inductor are surrounded by a seal ring, and

wherein the second inductor connects to the second circuit through the seal ring.

5. The semiconductor device according to claim 1, wherein the first circuit, the second circuit, the first external terminal, the second external terminal, the first wire, the second wire, and the first inductor are surrounded by a seal ring.

6. The semiconductor device according to claim 1, wherein the substrate comprises a scribe line region to surround a chip formation region, and the second inductor is provided around a seal ring.

7. The semiconductor device according to claim 1, wherein the second inductor is connected to the first circuit through the second circuit.

8. The semiconductor device according to claim 1, wherein the second inductor comprises a first end and a second end that are coupled to the second circuit.

9. The semiconductor device according to claim 1, further comprising:

a seal ring that, in a plan view, is surrounded by the second inductor,

wherein, in a plan view, the seal ring surrounds the first circuit, the second circuit, the first external terminal, the second external terminal, the first wire, the second wire, and the first inductor.

10. The semiconductor device according to claim 9, further comprising:

a chip formation region that, in a plan view, surrounds the seal ring.

11. The semiconductor device according to claim 10, wherein the substrate comprises a scribe line region that, in a plan view, surrounds the chip formation region.

12. The semiconductor device according to claim 1, wherein the first circuit comprises an internal circuit, the second circuit comprises a power supply circuit, the first inductor comprises a signal transmitting/receiving inductor, and the second inductor comprises a power receiving inductor.

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